

# The Genera *Praeglobotruncana*, *Rotalipora*, *Globotruncana*, and *Abathomphalus* in the Upper Cretaceous of Trinidad, B. W. I.

By Hans M. Bolli<sup>1</sup>

## Introduction

SINCE THE PUBLICATION of the author's papers on the genus *Globotruncana* and on the Upper Cretaceous stratigraphy of Trinidad (Bolli, 1951, 1952), much new paleontologic and stratigraphic information has been gained. It is the purpose of the present paper to describe those species of the genera *Praeglobotruncana*, *Rotalipora*, *Globotruncana* and *Abathomphalus* that were not known before, to discuss some changes in the previous results, and to show the stratigraphic distribution in Trinidad of all recorded species of these genera.

The highly complex geology of central and southern Trinidad, with its strongly distorted and incomplete surface sections, is not an inviting ground for detailed biostratigraphic studies. This applies in particular to the Upper Cretaceous sediments. The few, widely scattered outcrops are small, isolated slipmasses that do not offer continuous stratigraphic sections. It is only in recent years, during exploration activities in search of Cretaceous oil, that valuable paleontologic and stratigraphic information has come to light.<sup>2</sup> Wells drilled into and through the Upper Cretaceous have made available a number of sections which, combined, represent a fairly continuous succession of sediments. Although this combined sequence is not regarded as truly comprehensive—several stratigraphic gaps apparently still exist—it may now be said that its completeness is at least equal to many of the best known Upper Cretaceous sections in Central and South America.

The faunistic content of Trinidad's Upper Cretaceous sediments is variable, but more often than not the sediments contain rich fossil assemblages. Foraminifera are predominant in all formations. Only occasionally are they out-numbered by Radiolaria (in parts of the Naparima Hill formation). Mollusks may be numerous in the lower part of the Naparima Hill formation where they become valuable markers. The stratigraphic usefulness of certain species of *Didymotis* and some ammonites in these beds has been noted recently (Imlay, 1955).

About 450 different species and subspecies of Foraminifera are recognized today in Trinidad's Upper Cretaceous. Of these, about 380 belong to calcareous and arenaceous benthonic genera and the remaining 70 odd to planktonic genera. Of the latter, about 15 are classified under the various genera of the family Hantkeninidae and the genus *Rugoglobigerina*; another 20 under the genera *Guembelina*, *Pseudotextularia*, and *Ventilabrella*; and the remaining 35 under *Praeglobotruncana*, *Rotalipora*, *Globotruncana*, and *Abathomphalus*. Benthonic and planktonic Foraminifera are often present in equal numbers, though in the Guayaguayare and Gautier formations the latter predominate. The abundance and short range of many of the planktonic species make them ideally suited as markers for stratigraphic work in the Upper Cretaceous of Trinidad.

The generic position of several species discussed in this paper had to be changed according to the classification of planktonic Foraminifera proposed recently by Bolli, Loeblich, and Tappan (1957). *Globorotalia delrioensis* Plummer and *Globotruncana citae* Bolli are now included in *Praeglobotruncana*. *Globotruncana intermedia* Bolli and *G. mayaroensis* Bolli belong to *Abathomphalus*. Several Upper Cretaceous species published as *Globigerina* (e. g., *Globigerina gautierensis* Bronnemann) have been removed to the genus *Praeglobotruncana* since completion of this paper and are therefore omitted.

## Stratigraphy

The Upper Cretaceous sediments of Trinidad are at present grouped into the Gautier, Naparima Hill, and Guayaguayare formations. Because of non-deposition or subsequent erosion these formations show a very irregular pattern of distribution in central and south Trinidad. Strong tectonic movements in which they were involved have further complicated the study of the original sequence of the sediments.

Most outcrops are small isolated masses, each representing not more than one zone. The only exception is found in the Gautier River of the eastern Central Range (for detailed locality description, see p. 52). There, the black Gautier shales (*Rotalipora appenninica* zone) are seen in contact with strongly silicified beds of the Naparima Hill formation. Higher

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in the same section we find two small outcrops of the highly calcareous Guayaguayare formation (transition *Globotruncana gansseri*—*Abathomphalus mayaroensis* zone). The contact with the Naparima Hill formation is, however, not exposed.

Because of the virtual absence of surface sections it is fortunate that a number of subsurface profiles are available, thus permitting the study of a fairly continuous sequence of Upper Cretaceous foraminiferal faunas.

For reasons already mentioned, and because of the possibility of correlation with established type sections in Europe and North Africa, where the same forms are found, species of *Praeglobotruncana*, *Rotalipora*, *Globotruncana* and *Abathomphalus* have been chosen for the zoning. Several species that prove to be important markers in Europe and North Africa have not yet been recorded in Trinidad. *Rotalipora cushmani* (Morrow), *R. reicheli* Mornod, *R. turonica* Brotzen, and *Praeglobotruncana stephani* (Gandolfi) constitute one group of species absent so far from known Trinidad sections. They are restricted to the upper part of the Cenomanian. A widespread hiatus between the Gautier and Naparima Hill formations, with the Upper Cenomanian and probably the lower Turonian missing, may thus be assumed. *Globotruncana calcarata* Cushman, which is probably restricted to the upper part of the Campanian, is another form not yet recorded in Trinidad, suggesting that a minor stratigraphic gap is likely to exist between Naparima Hill formation and Guayaguayare formation. This is further supported by an abrupt change in lithology between the two formations.

Because the distribution of the various zones in Trinidad is so irregular, it is quite possible that the missing intervals are present but have not yet been found.

The Gautier formation consists of dark grey to black, noncalcareous or calcareous shales. Strongly indurated shales, sandstones and conglomerates may be interbedded. Based on faunistic evidence, the age is considered to be Albian to lower part of the Cenomanian. The formation is divided into the following zones (from top to bottom):

*Rotalipora appenninica appenninica* zone  
*Globigerina washilensis* zone  
*Rotalipora ticinensis ticinensis* zone

The *Rotalipora ticinensis ticinensis* and *Globigerina washilensis* zones have both been established in the subsurface section of Trinidad Leaseholds well Marac 1 (coordinates N:152141 links, E:424447 links). The type locality for the youngest zone is located in the Gautier River (right side branch of Cunapo River at junction of waterfall branch, north of Chert Hill, 1½ miles southeast of Mamon Guaioco-Tamana Road, eastern Central Range, coordinates N:331460 links, E:526400 links). Some of the samples collected there consist of up to 9 percent by weight of Foraminifera, predominantly Globorotaliidae and Planomaliniinae.

The maximum recorded thickness of the Gautier formation is about 2,000 feet.

The Naparima Hill formation consists in its upper part of argillite, a whitish to grey-brown siliceous indurated claystone with an average CaCO<sub>3</sub> content of 10 to 20 percent. Towards its base, the formation becomes increasingly well-bedded and shaly, with occasional interbedded sands; the colour then changes to dark grey or black. Based on megafossil and microfossil evidence, the Naparima Hill formation ranges from Turonian to Campanian. The following zones are distinguished (from top to bottom):

*Globotruncana stuarti* zone  
*Globotruncana fornicata* zone  
*Globotruncana concavata* zone  
*Globotruncana renzi* zone  
*Globotruncana inornata* zone

The bottom four zones had to be established in subsurface sections. In the *Globotruncana inornata* zone (Trinidad Petroleum Development well Moruga 15, coordinates N:149878 links, E:497002 links) are found the single-keeled *Globotruncana inornata*, new species, *G. schneegansi* Sigal, and *G. helvetica* Bolli, with no double-keeled species. The *Globotruncana renzi* zone (Trinidad Petroleum Development well Moruga 15, coordinates N:149878 links, E:497002 links) is defined by the first occurrence of double-keeled *Globotruncana* (*Globotruncana renzi* Gandolfi and *G. cf. lapparenti coronata* Bolli) and the absence of *Globotruncana concavata* (Brotzen), *G. wilsoni*, new species, and *G. fornicata* Plummer. Restricted to the *Globotruncana concavata* zone (Trinidad Leaseholds well Marac 1, coordinates N:151141 links, E:424447 links) are the zonal marker and *Globotruncana wilsoni*, new species. The *Globotruncana fornicata* zone (Trinidad Petroleum Development well Moruga 15, coordinates N:149878 links, E:497002 links) is characterized by the absence of *Globotruncana concavata* (Brotzen) and *G. stuarti* (de Lapparent) in an assemblage that contains *Globotruncana fornicata* Plummer.

As in the case of the Gautier formation, only the highest zone is known from the surface. Its type locality is the Naparima Hill in San Fernando (Usine Ste. Madeleine Quarry at the SE end of the hill; coordinates N:235800 links, E:364000 links). The zonal marker *Globotruncana stuarti* (de Lapparent) appears first in the upper part of the Naparima Hill formation, and continues into the Guayaguayare formation. The relatively scarce *Globotruncana ventricosa* White and *Praeglobotruncana coarctata*, new species, are confined to the *Globotruncana stuarti* zone. The maximum recorded thickness of the Naparima Hill formation is about 2,000 feet.

The Guayaguayare formation, consisting of blotchy, grey, highly calcareous shale, overlies the Naparima Hill formation. The major part of the formation is regarded as Maestrichtian, though its lower portion is of possible late Campanian age. Outcropping isolated slipmasses of the Guayaguayare formation have been discussed and described previously (Bolli, 1950,



1952). The formation is divided into the following zones (all established in the subsurface section of Trinidad Leaseholds well Guayaguayare 163, coordinates N:157646 links, E:572808 links):

*Abathomphalus mayaroensis* zone  
*Globotruncana gansseri* zone  
*Globotruncana lapparenti tricarinata* zone

The lowest zone of the Guayaguayare formation still lacks *Globotruncana gansseri* Bolli and *Abathomphalus mayaroensis* (Bolli), but abounds in several subspecies of *Globotruncana lapparenti* Brotzen, predominant among which is the zonal marker *Globotruncana lapparenti tricarinata* (Quereau). A few specimens of *Globotruncana andori* de Klasz were found in this zone. The following species do not range into the younger zones: *Globotruncana lapparenti lapparenti* Bolli, *G. lapparenti bulloides* Vogler, *G. lapparenti tricarinata* (Quereau), *G. globigerinoides* Brotzen, *G. fornicata* Plummer, and *G. repanda*, new species.

The marker for the *Globotruncana gansseri* zone has also been recorded from Turkey (under the synonym of *Globotruncana lugeoni* Tilev) and from mid-Pacific sea mounts (Hamilton, 1953). The author has seen it in material from Cuba and in the Navarro formation. *Globotruncana calciformis* (de Lapparent), *G. contusa* (Cushman), *G. gagebini* Tilev and *Abathomphalus intermedia* (Bolli) are other species occurring for the first time in the *Globotruncana gansseri* zone; they continue into the *Abathomphalus mayaroensis* zone.

The zonal marker of the *Abathomphalus mayaroensis* zone is a typical and apparently short-lived species which so far has not been recorded in publications from outside Trinidad. However, the author has seen specimens in material from the type locality of the Mendez shale (300 meters east of Mendez Station, kilometer 629.3 on the San Luis Potosi-Tampico railway, Mexico) and from Bavaria. An outcrop containing a fauna transitional between the *Globotruncana gansseri* and *Abathomphalus mayaroensis* zones is known from the Gautier River section (see p. 52).

The maximum recorded thickness of the Guayaguayare formation is about 500 feet.

### Evolutionary Trends

In recent years much has been written on the evolutionary trends of the genera under discussion. Hagn and Zeil (1954, pp. 51-56) gave a condensed review of the various interpretations. Although there might be a relatively simple general pattern in the phylogeny of *Praeglobotruncana*, *Rotalipora*, *Globotruncana*, and *Abathomphalus*, the details are complex and little studied.

The evolutionary trend in *Rotalipora*, from a single inflated early form to several compressed later species, seems to be fairly well established. Of special interest is the pattern of coiling during the evolution of *Rotalipora*. As may be expected, the early species, *Rotalipora roberti* (Gandolfi) and *R. vicinensis* (Gandolfi), coil at random, later becoming predominantly dextral in the

*Rotalipora appenninica* (Renz)—*R. reicheli* Mornod group. Before the extinction of the genus, its latest representatives, *Rotalipora turonica* Brotzen and *R. cushmani* (Morrow), unexpectedly revert to random coiling. This might represent a gerontic stage. Whereas abrupt changes in coiling from one preferred direction to the opposite one are known to take place in later evolutionary stages of certain *Globorotalia* species (Bolli, 1950), such a return to random coiling had not, to the author's knowledge, been observed before.

Transitional stages exist between certain *Rugoglobigerina* and *Globotruncana* species. This suggests a close generic relationship of at least a number of *Globotruncana* species with *Rugoglobigerina* species. It may be assumed that species of *Globotruncana* branched off independently from rugoglobigerinid forms on more than one occasion between Turonian and Maestrichtian time. One of the first attempts by *Rugoglobigerina* to produce forms with one or more peripheral keels and compressed chambers took place in the Turonian and led to the short lived *Globotruncana helvetica* Bolli which has no apparent direct descendants. The single-keeled *Globotruncana schneegansi* Sigal developed independently at approximately the same time from similar forms, possibly via *Globotruncana inornata*, new species. This seems to have been a more successful mutation, as it appears that the single-keeled *Globotruncana schneegansi* gave rise to the double-keeled *Globotruncana renzi* Gandolfi—*G. angusticarinata* Gandolfi—*G. concavata* (Brotzen)—*G. ventricosa* White suite. However, the possibility that the single keeled *Globotruncana schneegansi* might have developed from late representatives of *Praeglobotruncana stephani* (Gandolfi) should not be overlooked. A tendency is observed in late representatives of *Praeglobotruncana stephani* for the aperture to move from an interior-marginal, extraumbilical-umbilical position to an umbilical one.

*Globotruncana wilsoni*, new species, appears to have developed independently from *Rugoglobigerina* ancestors in early Senonian time. This species may have given rise subsequently to the *Globotruncana fornicata* Plummer—*G. contusa* (Cushman) suite.

*Globotruncana globigerinoides* Brotzen whose relation to rugoglobigerine forms is obvious, is a comparative latecomer, appearing in Trinidad only after many other typical *Globotruncana* species have already become extinct. It initiates another attempt by the *Rugoglobigerinas* to change their shape. *Globotruncana lapparenti bulloides* Vogler and *G. lapparenti tricarinata* (Quereau) are connected by transition to *G. globigerinoides*; they are to a large degree contemporaneous.

The Campanian *Globotruncana repanda*, new species, is short lived and likely to have sprung directly from a *Rugoglobigerina* ancestor.

*Globotruncana gansseri* Bolli, which is morphologically similar to the Turonian *Globotruncana helvetica* Bolli, appears in the Maestrichtian, again with transitional

rugoglobigerinid forms. Like *Globotruncana helvetica*, it is a short-lived offshoot from a *Rugoglobigerina* species. The Maestrichtian *Trinitella scotti* Bronnmann (= *Rugoglobigerina*) with its compressed end chambers is further proof of the repeated and seemingly independent attempts of the Turonian-Maestrichtian *Rugoglobigerinae* to develop one or two peripheral keels.

This brief outline of the probable phylogenetic pattern demonstrates the close relationship between the genera *Rugoglobigerina* and *Globotruncana* and at the same time throws light on the artificial division into two genera of planktonic Foraminifera that are genetically closely related. The identical pattern of coiling is further proof of such relationship. All species of both groups maintain a strong preference for dextral coiling from the Turonian to their contemporaneous extinction in the Maestrichtian. An earlier evolutionary stage with random coiling such as is found in certain Oligo-Miocene *Globorotalia* species (Bolli, 1951) or in *Rotalipora* may be expected in Cenomanian ancestors.

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## Systematic Descriptions

### Family Globorotaliidae Cushman, 1927

#### Genus *Praeglobotruncana* Bermudez, 1952

##### *Praeglobotruncana* cf. *delrioensis* (Plummer)

##### PLATE 12, FIGURES 4a-c

*Globorotalia delrioensis* PLUMMER, Univ. Texas Bull. 3101, p. 199, pl. 13, figs. 2a-c, 1931.

Shape of test: low trochospiral, biconvex; equatorial periphery slightly lobate, no distinct keel. Wall: calcareous, perforate, surface smooth. Chambers: moderately compressed; about 12, arranged in 2½ to 3 whorls; the 5 chambers of the last whorl increase rapidly in size; early whorls small by comparison. Sutures: spiral side curved, depressed; umbilical side nearly radial, depressed. Umbilicus: details obscure; part appears to be covered by extensions of chambers. Aperture: An interiomarginal, extraumbilical-umbilical slit. Coiling: Random; of the 8 specimens counted, 5 coiled dextrally.

Dimensions of figured hypotype: Diameter 0.32 mm.; thickness 0.15 mm.

RANGE: *Globigerina washitensis* zone and *Rotalipora appenninica appenninica* zone, Gautier formation.

TYPE AND OCCURRENCE: Figured specimen (USNM P4793) from Trinidad Leaseholds well Marac 1, Trinidad (coordinates N:152141 links, E:424447 links), sample at 9,773 feet (TLL 177171).

##### *Praeglobotruncana coarctata* Bolli, new species

##### PLATE 12, FIGURES 2a-3c

Shape of test: very low trochospiral, biconvex;

equatorial periphery lobate; a faint keel is often observed in last chambers; it may be ornamented with minute spines on peripheral edge. Wall: calcareous, perforate, surface smooth. Chambers: strongly compressed; 10-12, arranged in 2 whorls; the 5-6 chambers of the last whorl increase rapidly in size; the early whorl minute by comparison. Sutures: spiral side radial or slightly curved, depressed; umbilical side radial, depressed. Umbilicus: each chamber of last whorl extends towards the center, leaving only a small portion open. Aperture: a low arched, interiomarginal, extraumbilical-umbilical slit. Coiling: predominantly dextral; of 37 specimens counted, only 4 coiled sinistrally.

Dimensions of holotype: diameter 0.4 mm.; thickness 0.16 mm.

RANGE: *Globotruncana stuarti* zone, Naparima Hill formation.

TYPES AND OCCURRENCE: Usine Ste. Madeleine Quarry, southeast end of Naparima Hill, San Fernando, Trinidad (coordinates N:235800 links, E:364000 links). Holotype (USNM P4794) from sample Bt. 37 (TLL 151935); figured paratype (USNM P4795) from sample Bt. 46 (TLL 151943).

REMARKS: *Praeglobotruncana coarctata*, new species, differs from *Praeglobotruncana citae* (Bolli) in having an almost flat spiral side instead of a convex one and in having usually five chambers in the last whorl instead of four.

Genus *Rotalipora* Brotzen, 1942*Rotalipora ticinensis ticinensis* (Gandolfi)

## PLATE 12, FIGURES 1a-c

*Globotruncana ticinensis* GANDOLFI, Riv. Italiana Paleontol. Stratigr., vol. 48, Suppl. Mem. 4, pp. 113-135, pl. 2, figs. 3, 4, 1942.

*Thalmaninella ticinensis ticinensis* (Gandolfi), REICHEL, Eclog. Geol. Helvetiae, vol. 42, pt. 2, p. 603, pl. 16, fig. 6, and pl. 17, fig. 6, 1949.

Shape of test: low trochospiral, biconvex, with spiral side slightly more convex; equatorial periphery nearly circular, with single keel. Wall: calcareous, perforate, surface smooth. Chambers: compressed; 18-20, arranged in 2½-3 whorls; the 7-8 chambers of the last whorl increase slowly in size. Sutures: spiral side curved, depressed, occasionally slightly raised; umbilical side radial, depressed. Umbilicus: details obscure; part appears to be covered by extensions of chambers. Apertures: primary aperture an interiomarginal, umbilical-extraumbilical slit; no secondary sutural apertures have been observed in the rather poorly preserved Trinidad specimens. Coiling: random; of the 25 specimens counted, 15 coiled sinistrally.

Dimensions of figured hypotype: diameter 0.31 mm.; thickness 0.11 mm.

RANGE: *Rotalipora ticinensis ticinensis* zone, Gautier formation.

TYPE AND OCCURRENCE: Figured hypotype (USNM P4792) from Trinidad Leaseholds well Marac 1, Trinidad (coordinates N:152141 links, E:424447 links), sample at 11,979 feet (TLL 178532).

## Family Globotruncanidae Brotzen, 1942

Genus *Globotruncana* Cushman, 1927*Globotruncana helvetica* Bolli

## PLATE 13, FIGURE 1 a-c

*Globotruncana helvetica* BOLLI, Eclog. Geol. Helvetiae, vol. 26, No. 2, p. 226, pl. 9, figs. 6-8, figs. 9-12 of text-fig. 1, 1945.—SIGAL, 19th Congr. Géol. Internat., Monogr. Rég., ser. 1, No. 26, p. 31, fig. 32 1952.—HAGN and ZEIL, Eclog. Geol. Helvetiae, vol. 47, No. 1, p. 30, pl. 3 figs. 1a-c, 1954.

Shape of test: very low trochospiral; spiral side almost flat, inner whorls often slightly raised, umbilical side strongly inflated; equatorial periphery lobate, in well developed specimens a distinct keel is present though it is often weakened in the last chamber; specimens with faint or missing keels, transitional to rugoglobigerine forms, were observed in material from Tunisia. Wall: calcareous, perforate, surface rugose especially on umbilical side. Chambers: hemispherical; 15-18, arranged in 2-3 whorls; the 5 chambers of the last whorl increase rapidly in size, early whorl is small by comparison. Sutures: spiral side curved, depressed; umbilical side almost radial, depressed. Umbilicus:

deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures not preserved in examined specimens. Coiling: the few specimens recorded so far in Trinidad coil dextrally; of 100 specimens counted in a sample from Tunisia, 98 coiled dextrally.

Dimensions of figured hypotype: diameter 0.44 mm.; thickness 0.24 mm.

RANGE: *Globotruncana inornata* zone, Naparima Hill formation.

TYPE AND OCCURRENCE: Figured hypotype (USNM P4796) from Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links, E:497002 links), sample from core 6980-7005 feet (TLL 228918).

*Globotruncana repanda* Bolli, new species

## PLATE 13, FIGURES 2 a-c

Shape of test: very low trochospiral, spiral side concave, umbilical side strongly inflated; equatorial periphery lobate, early chambers of last whorl with double keel, which may be absent in the ultimate and penultimate chambers. Wall: calcareous, perforate; surface in well preserved specimens slightly rugose, especially on the umbilical side. Chambers: globular to hemispherical; 12-15, arranged in 2-3 whorls; the 4 chambers of the last whorl increase rapidly in size, earlier whorls small by comparison. Sutures: spiral side almost radial, depressed; umbilical side radial, depressed. Umbilicus: deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures not preserved in Trinidad material, but present in specimens of this species from the Gulf Coast. Coiling: the 25 specimens counted all coiled dextrally.

Dimensions of holotype: diameter 0.4 mm.; thickness 0.24 mm.

RANGE: *Globotruncana fornicata* zone to *Globotruncana lapparenti tricarinata* zone, Naparima Hill formation. Holotype from *Globotruncana stuarti* zone, Naparima Hill formation.

TYPE AND OCCURRENCE: Holotype (USNM P4797) from Usine Ste. Madeleine Quarry, southeast end of Naparima Hill, San Fernando, Trinidad (coordinates N:235800 links, E:364000 links), sample Bt. 37 (TLL 151935).

REMARKS: In its planoconvex shape, *Globotruncana repanda*, new species, shows similarities to *G. helvetica* Bolli, *G. gansseri* Bolli, *G. concavata* (Brotzen), and *G. ventricosa* White. It differs from the last two by having in the last whorl fewer and more inflated chambers, which are bent upwards on the spiral side. It is usually slightly smaller in size. From *Globotruncana helvetica* and *G. gansseri* the new species differs in having two peripheral keels, a more concave spiral side, and a less rugose surface. The stratigraphic range of *Globotruncana repanda* is similar to that of *G. ventricosa* but differs considerably from that of the other three species.

*Globotruncana concavata* (Brotzen)

## PLATE 13, FIGURES 3a-c

*Rotalia concavata* BROTZEN, Zeitschr. Deutsch. Ver. Palaestinas, vol. 57, p. 66, pl. 3, fig. b, 1934.

*Globorotalia asymetrica* SIGAL, 19th Congr. Géol. Internat., Monogr. Rég., ser. 1, No. 26, p. 35, fig. 35, 1952.

*Globotruncana (Globotruncana) ventricosa ventricosa* White, DALBIEZ, Micropaleontology, vol. 1, No. 2, p. 163, figs. 7a-d, 1955.

Shape of test: very low trochospiral, spiral side often slightly concave, umbilical side strongly convex; equatorial periphery distinctly lobate with closely spaced double keel. Wall: calcareous, perforate, surface smooth. Chambers: hemispherical; 15-20, arranged in 3-3½ whorls; the 5-6 chambers of the last whorl increase rapidly in size, early whorls small by comparison. Sutures: spiral side distinctly curved, depressed; umbilical side radial, depressed. Umbilicus: deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures not preserved in examined specimens. Coiling: predominantly dextral; of 50 specimens counted, only 3 coiled sinistrally.

Dimensions of figured hypotype: diameter 0.69 mm.; thickness 0.4 mm.

RANGE: *Globotruncana concavata* zone, Naparima Hill formation.

TYPE AND OCCURRENCE: Figured hypotype (USNM P4798) from Trinidad Leaseholds well Marac 1, Trinidad (coordinates N:152141 links, E:424447 links), sample from core 8,180-8,237 feet (TLL 175917).

REMARKS: The characteristic features of *Globotruncana concavata* (Brotzen) are similar to those of *Globotruncana ventricosa* White. Through the courtesy of Dr. B. F. Ellis, some specimens of *Globotruncana ventricosa* from White's original collection at Columbia University, N. Y., were obtained for comparison with specimens of *Globotruncana concavata* from Israel (original locality), Tunisia, and Trinidad. It was found that the two species differ as follows:

*Globotruncana ventricosa* as a rule has 6-7 chambers in the last whorl with slightly more oblique sutures on the spiral side, as against usually 5 chambers with slightly curved sutures in *Globotruncana concavata*. The spiral side of *Globotruncana concavata* is often slightly concave, that of *Globotruncana ventricosa* is flat or slightly raised. Compared with *Globotruncana concavata*, the 2 peripheral keels in *Globotruncana ventricosa* are a little further apart and more strongly developed, and the sutures are often beaded. Finally, the stratigraphic range of the two species is different: *Globotruncana concavata* appears to be restricted to the upper part of the Coniacian and the Lower Santonian, *Globotruncana ventricosa* to the Upper Santonian and the Campanian. Because of their similarity, the two species may easily be mistaken. The specimen figured by Dalbiez (1955) as *Globotruncana ventricosa ventricosa* is, in the author's opinion, a *Globotruncana concavata*. *Globotruncana ventricosa carinata* Dalbiez is probably identical to *Globotruncana ventricosa* White, while

*Globotruncana ventricosa primitiva* Dalbiez could be close to *Globotruncana renzi* Gandolfi, judging from the single peripheral view given by Dalbiez and the stratigraphic range quoted by him. According to Dalbiez's range chart, the three species (*Globotruncana ventricosa primitiva* (= *G. renzi*), *G. ventricosa ventricosa* (= *G. concavata*) and *G. ventricosa carinata* (= ?*G. ventricosa* White) follow each other in time. Transitional specimens suggest that they probably represent an evolutionary sequence.

*Globotruncana ventricosa* White

## PLATE 13, FIGURES 4a-c

*Globotruncana canaliculata* var. *ventricosa* WHITE, Journ. Paleontol. vol. 2, No. 4, p. 284, pl. 38, figs. 5a-c, 1928.

Shape of test: very low trochospiral, nearly flat or slightly convex on spiral side, strongly convex on the umbilical side; equatorial periphery lobate, with distinct, robust double keel, often weakened in last chambers. Wall: calcareous, perforate, surface smooth. Chambers: angular, inflated; 15-20, arranged in 2½-3 whorls; the 6-7 chambers of the last whorl increase moderately in size. Sutures: spiral side: curved, strongly raised, beaded in early portion; umbilical side: slightly curved, depressed. Umbilicus: deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures not preserved in examined specimens. Coiling: the limited number of specimens seen coiled dextrally.

Dimensions of figured hypotype: diameter 0.63 mm.; thickness 0.34 mm.

RANGE: *Globotruncana stuarti* zone, Naparima Hill formation.

TYPE AND OCCURRENCE: Figured hypotype (USNM P4799) from Usine Ste. Madeleine Quarry, southeast end of Naparima Hill, San Fernando, Trinidad (coordinates N:235800 links, E:364000 links), sample Bt. 37 (TLL 151935).

REMARKS: See remarks under the description of *Globotruncana concavata* (Brotzen).

*Globotruncana inornata* Bolli, new species

## PLATE 13, FIGURES 5a-6c

Shape of test: low trochospiral, biconvex; equatorial periphery strongly lobate, early chambers of last whorl rounded at periphery, last and occasionally penultimate chambers compressed with sharp peripheral edge or faint keel. Wall: calcareous, perforate, surface of early chambers in well preserved specimens showing some rugosity. Chambers: subangular, compressed; 14-16, arranged in 3 whorls; the 4 chambers of the last whorl increase rapidly in size, early whorls small by comparison. Sutures: spiral side slightly curved, depressed; umbilical side: straight, depressed. Umbilicus: shallow, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures poorly preserved in examined specimens. Coiling: predominantly dextral; of 50 specimens counted, only 4 coiled sinistrally.

Dimensions of holotype: diameter 0.44 mm.; thickness 0.2 mm.

RANGE: *Globotruncana inornata* zone to *Globotruncana concavata* zone, Naparima Hill formation. Holotype from *Globotruncana renzi* zone, Naparima Hill formation. Similar forms seem to extend into the *Globotruncana formicata* and *G. stuarti* zones of the Naparima Hill formation.

TYPES AND OCCURRENCE: Figured types from Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links, E:497002 links). Holotype (USNM P4800) from core 6,802-6,827 feet (TLL 223498), paratype (USNM P4801) from core 6,980-7,005 feet (TLL 223504).

REMARKS: *Globotruncana inornata*, new species, differs from *Globotruncana wilsoni*, new species, in having the early chambers of the last whorl rounded at the periphery rather than with a double keel. It also has a longer stratigraphic range than *Globotruncana wilsoni*, new species.

*Globotruncana schneegansi* Sigal

PLATE 14, FIGURES 1a-c

*Globotruncana schneegansi* SIGAL, 19th Congr. Géol. Internat., Monogr. Rég., ser. 1, No. 26, p. 33, fig. 34, 1952.

Shape of test: low trochospiral, biconvex; equatorial periphery lobate, with distinct single keel on all chambers of last whorl. Wall: calcareous, perforate, surface smooth. Chambers: angular, strongly compressed; about 14, arranged in  $2\frac{1}{2}$ -3 whorls; the 5 chambers of the last whorl increase rapidly in size, early whorls small by comparison. Sutures: spiral side curved, raised, beaded; umbilical side radial, depressed. Umbilicus; shallow, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures not preserved in examined specimens. Coiling: the limited number of specimens seen coiled dextrally.

Dimensions of figured hypotype: diameter 0.6 mm.; thickness 0.2 mm.

RANGE: *Globotruncana inornata* zone to *Globotruncana renzi* zone, Naparima Hill formation.

TYPE AND OCCURRENCE: Figured hypotype (USNM P4802) from Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links, E:497002 links), sample from core 6,980-7,005 feet (TLL 223504).

*Globotruncana renzi* Gandolfi

PLATE 14, FIGURES 3a-c

*Globotruncana appenninica-linnei* O. RENZ, *Ecol. Geol. Helvetiae* vol. 29, No. 1, pl. 6, figs. 16-19, 21, and pl. 8, figs. 2, 3, 5, 1936.

*Globotruncana renzi* GANDOLFI, *Riv. Italiana Paleontol., Stratigr.*, vol. 48, Suppl. Mem. 4, p. 124, pl. 3, figs. 1a-c, pl. 4, figs. 15, 16, 23, 29, 1942.—HAGN and ZELL, *Ecol. Geol. Helvetiae*, vol. 47, No. 1, p. 37, pl. 3, figs. 2a-c, 1954.

Shape of test: low trochospiral, biconvex; equatorial periphery slightly lobate, with closely spaced double keel in early chambers of last whorl; last and occa-

sionally penultimate chambers with a single keel only. Wall: calcareous, perforate, surface smooth. Chambers: angular, strongly compressed; about 14, arranged in  $2\frac{1}{2}$ -3 whorls; the 5 chambers of the last whorl increase rapidly in size, early whorls small by comparison. Sutures: spiral side curved, slightly raised in last whorl, occasionally beaded, in early part depressed; umbilical side depressed, radial or slightly curved. Umbilicus: shallow, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures not preserved in examined specimens. Coiling: the limited number of specimens seen coiled dextrally.

Dimensions of figured hypotype: diameter 0.6 mm.; thickness 0.23 mm.

RANGE: *Globotruncana renzi* to *Globotruncana concavata* zone, Naparima Hill formation.

TYPE AND OCCURRENCE: Figured hypotype (USNM P4803) from Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links, E:497002 links), sample from core 6,802-6,827 feet (TLL 223498).

*Globotruncana* cf. *lapparenti coronata* Bolli

PLATE 14, FIGURES 2a-c

?*Globotruncana lapparenti coronata* BOLLI, *Ecol. Geol. Helvetiae*, vol. 37, No. 2, p. 233, pl. 9, figs. 14, 15, and figs. 21 and 22 of text fig. 1, 1944.

?*Globotruncana coronata* Bolli, SIGAL, 19th Congr. Géol. Internat., Monogr. Rég., ser. 1, No. 26, p. 34, fig. 36, 1952.

Shape of test: low trochospiral, biconvex; equatorial periphery lobate, with closely spaced double keel. Wall: calcareous, perforate, surface smooth. Chambers: angular, strongly compressed; about 14, arranged in  $2\frac{1}{2}$ -3 whorls; the 5 chambers of the last whorl increase rapidly in size; early whorls small by comparison. Sutures: spiral side curved, depressed or slightly raised in ultimate whorl, depressed in early portion; umbilical side slightly curved, depressed. Umbilicus: shallow, wide. Apertures: primary apertures interiomarginal, umbilical. Tegilla with accessory apertures not preserved in examined specimens. Coiling: the limited number of specimens seen coiled dextrally.

Dimensions of figured specimen: diameter 0.56 mm.; thickness 0.2 mm.

RANGE: *Globotruncana renzi* to *Globotruncana concavata* zone, Naparima Hill formation.

TYPE AND OCCURRENCE: Figured specimen (USNM P4804) from Trinidad Petroleum Development well Moruga 15, Trinidad (coordinates N:149878 links, E:497002 links), sample from core 6,519-6,544 feet (TLL 223495).

REMARKS: The Trinidad specimens are slightly smaller than the typical forms from the Alpine-Mediterranean region.

*Globotruncana wilsoni* Bolli, new species

PLATE 14, FIGURES 4a-c

Shape of test: low trochospiral, biconvex; equatorial periphery lobate, early chambers of last whorl with a



faint double keel, which is reduced to a single keel in the last and penultimate chamber. Wall: calcareous, perforate, surface smooth. Chambers: moderately compressed; 12-15, arranged in 3 whorls; the 4 chambers of the last whorl increase rapidly in size, early whorls small by comparison. Sutures: spiral side slightly curved, depressed; umbilical side nearly radial, depressed. Umbilicus: wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures not preserved in examined specimens. Coiling: the 50 specimens counted coiled dextrally.

Dimensions of holotype: diameter 0.49 mm.; thickness 0.24 mm.

RANGE: *Globotruncana concavata* zone, Naparima Hill formation.

TYPE AND OCCURRENCE: Holotype (USNM P4805) from Trinidad Leaseholds well Marac 1, Trinidad (coordinates N:152141 links, E:424447 links), sample from core 8,332-8,362 feet (TLL 176080).

REMARKS: *Globotruncana wilsoni*, new species, differs from *Globotruncana lapparenti bulloides* Vogler in having only 4 chambers in the last whorl. The general outline of the equatorial periphery is more oval compared with the more circular form of *bulloides*, and the 2 keels are more closely spaced and often reduce to one in the last chamber. *Globotruncana wilsoni*, new species, occurs in the *Globotruncana concavata* zone, before the advent of typical *Globotruncana lapparenti bulloides*. Transitional forms between *Globotruncana wilsoni*, new species, and *Globotruncana fornicata* Plummer have been observed.

The species is named in honor of Mr. C. C. Wilson, Chief Geologist of Trinidad Petroleum Development, Ltd.

*Globotruncana gagnebini* Tilev

PLATE 14, FIGURES 5a-c

*Globotruncana gagnebini* TILEV, Bull. Lab. Géol., Min., Géophys., Mus. Géol., Univ. Lausanne, No. 103, p. 50, pl. 3, figs. 2-5, and text figs. 14a-17d, 1952.

Shape of test: very low trochospiral, dorsal side flat, umbilical side strongly convex; equatorial periphery distinctly lobate with 2 closely spaced keels, occasionally reduced to one in last chamber. Wall: calcareous, perforate, surface smooth. Chambers: angular, inflated; about 14, arranged in 2½ whorls; the 4-5 chambers of the last whorl increase rapidly in size, early whorls small by comparison. Sutures: spiral side curved, raised, beaded in early whorls; umbilical side radial, depressed. Umbilicus: deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures missing or only poorly preserved in examined specimens. Coiling: predominantly dextral; of 50 specimens counted, only 2 coiled sinistrally.

Dimensions of figured hypotype: diameter 0.48 mm.; thickness 0.23 mm.

RANGE: *Globotruncana gansseri* zone to *Abathomphalus mayaroensis* zone, Guayaguayare formation.

TYPE AND OCCURRENCE: Figured hypotype (USNM

P4806) from outcrop on right bank of Gautier River (right side branch of Cunapo River) about 1,100 feet southwest, above junction of waterfall branch (Chert Hill), 1¼ miles southeast of Mamon-Guaico-Tamana Road, eastern Central Range. Sample G. 3644A (TLL 226184).

REMARKS: In its general shape, *Globotruncana gagnebini* Tilev shows similarities to *Globotruncana ventricosa* White but differs in the following: 4-5 chambers in last whorl, rapidly increasing in size, against 6-7 in *Globotruncana ventricosa*, where the increase in size is slower. The peripheral double keel is less pronounced in *gagnebini* and the stratigraphic range is different (Maestrichtian for *Globotruncana gagnebini*, Campanian for *Globotruncana ventricosa*). Furthermore, *Globotruncana gagnebini* is somewhat smaller in size and less robust. The *Globotruncana ventricosa* of Maestrichtian age mentioned by the author in his earlier paper (1951) on Trinidad *Globotruncana* are now regarded as *Globotruncana gagnebini*. Typical *Globotruncana ventricosa* have been recorded in Trinidad from the upper part of the Naparima Hill formation.

*Globotruncana andori* de KLASZ

PLATE 14, FIGURES 6a-c

*Globotruncana andori* DE KLASZ, Geol. Bavarica, No. 17, p. 233, pl. 6, figs. 1a-c, 1953.

Shape of test: very low trochospiral, spiral side almost flat, umbilical side strongly convex; equatorial periphery nearly circular, with distinct single keel. Wall: calcareous, perforate, surface smooth. Chambers: subangular, inflated; about 15, arranged in 2-3 whorls, 6 chambers in last whorl. Sutures: spiral side curved, raised, slightly beaded; umbilical side slightly curved, slightly depressed. Umbilicus: deep, wide. Apertures: primary apertures interiomarginal, umbilical; tegilla with accessory apertures not preserved in examined specimens. Coiling: the limited number of specimens counted coiled dextrally.

Dimensions of figured hypotype: diameter 0.67 mm., thickness 0.47 mm.

RANGE: *Globotruncana lapparenti tricarinata* zone, Guayaguayare formation.

TYPE AND OCCURRENCE: Figured hypotype (USNM P4807) from Trinidad Leaseholds well Guayaguayare 163, Trinidad (coordinates N:157646 links, E:572808 links), sample from 5,961½ feet (TLL 153681).

REMARKS: Note that the species *Globotruncana cretacea* Cushman and *G. cf. calcarata* Cushman, which were mentioned as occurring in Trinidad (Bolli, 1951), are left out of the present distribution chart. Forms originally referred to as *Globotruncana cretacea* are now regarded as being closer to *Globotruncana gagnebini* Tilev. The specimens of *Globotruncana cf. calcarata* (Bolli, 1951, pl. 35, figs. 16-18) differ in size and shape from the typical form. They have only been found so far reworked in the Upper Eocene. Though it is likely that they come from the Guayaguayare formation, the exact stratigraphic position remains uncertain.

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